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BUREAU OF DAIRY INDUSTRY

CIRCULAR No. 165 AUGUST, 1931

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

PLOWING AS A CONTROL MEASURE FOR THE EUROPEAN CORN BORER IN WESTERN NEW YORK

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INTRODUCTION

When the European corn borer (*Pyrausta nubilalis* Hübner) was first discovered in western New York in the fall of 1919, it was found infesting a small area along the shore of Lake Erie, southwest of the city of Buffalo. Although at this time the insect was not causing serious injury in this area, infestations were so severe in the older areas in Massachusetts and eastern New York as to warn the United States Department of Agriculture that it might continue its westward spread and ultimately infest the great corn areas of the Middle West.

In order to secure information which would aid in checking the westward movement of the borer, plans were made in 1920 to study the insect carefully in what was then a new area of infestation and to test any suggested control measures which might reduce the intensity of existing infestations or retard the spread of the insect. With these objects in mind, a laboratory was established at Silver Creek, N. Y., in that year, and surveys were conducted which determined the existing limits and density of the infestation. Of the various possible control measures suggested, all good farm practices which might become factors in mechanical control were carefully studied. In the 2-generation area of New England, as well as in the single-generation area of western New York, the plowing under of stalks, stubble, and other infested materials became the subject of considerable investigational work. The information obtained from such plowing and burial experiments in western New York, given in detail in the following pages, is not necessarily applicable to other areas.

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EARLY EXPERIMENTS WITH HAND BURIALS

FALL OF 1920 AND SPRING OF 1921

During the fall of 1920 and the spring of 1921 the Bureau of Entomology of the United States Department of Agriculture undertook a vigorous campaign of suppression against the European corn borer in an area of about 25 square miles in the vicinity of Silver Creek, N. Y. During the course of this experimental clean-up campaign many methods of control were tested thoroughly for the first time, such as steaming, crushing, shredding, cutting, burning, and burying infested material. From these tests it became evident that the burying of infested material, preferably by cultural operations, offered great possibilities and that the department would be warranted in devoting considerable time and study to this means of control. Large quantities of infested material were buried in pits to a depth of 24 inches or more. Examination of the pits in the spring of 1921 resulted in the recovery of less than 1 per cent of the total number of larvae originally buried, and those recovered were dead and badly decomposed. Although this experimental method of burying larvae indicated that a 100 per cent kill resulted, it could not be recommended as a practical control operation because of the labor involved.

Similar burials, at varying depths and in various types of soil, were made during the three following seasons, both in the spring and in the fall, in order to determine the reaction of corn-borer larvae when hand-buried. In many of these earlier experiments various types of cages and traps were used in order to confine the larvae to a very definite known area where larval activity might be easily observed. Series of burials in which no cage restrictions were used were run parallel to burials in cages, in order to simulate field conditions as much as possible. Two types of test cages were used at first, both of which were efficient in many respects, yet it was impossible to avoid unnatural conditions which to some extent directly affected larval activity. The object of these earlier experiments, as already stated, was primarily to determine the movements of larvae when buried in the soil, whether there was migration to the soil surface, or whether such larvae perished in the soil as a result of interment.

The first type of test cage, which was known as the cylinder type, consisted of a cylinder of heavy galvanized-iron sheeting, 6 inches in diameter and 15 inches in length. Cages of this type, containing infested material buried at depths ranging from 4 to 12 inches, were placed in the ground. A trap consisting of noninfested cornstalk sections was placed on the soil surface within the cage as a shelter for migrating larvae, and 20-mesh screening was fastened over the top of the cylinder to prevent larvae from escaping. The box-type cage was constructed of hard pine boards, 12 inches in width, carefully nailed at the corners to make tight joints, and care was also taken to cover all knot holes and checks with 20-mesh wire screen. These cages were constructed in two sizes, viz, 14 by 17 inches, and 36 by 60 inches. The box-type cage was also covered with 20-mesh wire screen, which was cut full enough to overlap and allow it to be held in place by split laths fastened with brads to the outside of the cage. A recovery trap consisting of strips of double-corrugated strawboard, 1¼ inches wide, was attached on the inside of the cage, 2 inches below the tops of the boards, and held in place by split laths fastened to the

boards with 1-inch wire brads. The laths were held far enough away from the boards to admit the strawboard and allow it to rest upon the brads. The strawboard was so cut that its corrugations ran vertically, forming spaces or cells, 1¼ inches long, in which larvae could find shelter.

Some of the results of these earlier experiments were indicative of certain larval reactions which later were found to be caused by cage restrictions and which were not present under ordinary field conditions. Although some of the information obtained from the earlier experiments was later shown to be erroneous, the work conducted during this early period was, nevertheless, of great importance. The results obtained from the many series of burials enabled the authors to draw fairly definite conclusions regarding the behavior of buried larvae.

FALL OF 1921

The deep burials made in 1920 gave promising results, but since under farm conditions it would be impractical to bury large quantities of material to a depth of 24 inches, it became necessary to conduct experiments in burying infested stalks to a depth which would correspond more closely with the average depth of plowing employed by farmers. Two experiments were conducted in the fall of 1921, the results of which strengthened the belief that the plowing under of infested material might prove to be a practical method of corn-borer control.

The first experiment consisted of 10 shallow pits, each containing infested material buried to a depth of 8 inches. The results corresponded very closely with those obtained from the deep burials conducted in the fall of 1920, but since no traps were used at the surface in either experiment it was impossible to learn what became of most of the larvae. The comparatively small number of dead larvae found in the buried stalks and surrounding soil provided no information concerning the fate of the missing individuals.

The second experiment conducted during the fall of 1921 consisted of 42 cylinder traps in which infested material was buried on November 5. In order to obtain information concerning the effect of depth of burial, the experiment was divided into three series, each series containing 14 traps, in which the infested material was buried to depths of 4, 6, and 8 inches, respectively. The cylinders were left open when the experiment was started on November 5, but on December 1 it was decided to cover the tops with wire screening in order to confine any larvae which might reach the surface. A cage from each series was opened and examined at regular intervals during the winter and spring, the last ones being opened on June 10, 1922. About 55 per cent of all larvae buried were recovered. Many living individuals were found in the soil of the cages which were examined in the fall, but soil examinations made in the spring produced no living larvae. Approximately 45 per cent of the buried larvae were not recovered. Some of them may have escaped during the period when the traps were unprovided with screen tops, and others may have died and disintegrated in the soil. Practically no difference was noted in the amount of migration found in the three series; and the results indicated that depth of burial, within certain practical limits, had little effect upon the number of larvae that reached the soil surface. (Table 1.)

TABLE 1.—*Migration and survival of corn-borer larvae buried in soil at depths of 4, 6, and 8 inches, November 5, 1921, Silver Creek, N. Y.*

Date cylinders were examined	Larvae (5 per cylinder) buried 4 inches deep				Larvae (5 per cylinder) buried 6 inches deep				Larvae (5 per cylinder) buried 8 inches deep			
	Cylinder No.	Larvae recovered		Larvae missing	Cylinder No.	Larvae recovered		Larvae missing	Cylinder No.	Larvae recovered		Larvae missing
		Dead	Living			Dead	Living			Dead	Living	
1921												
Nov. 25	1	0	4	1	1	0	4	1	1	0	4	1
Dec. 15	2	0	4	1	2	0	1	4	2	1	3	1
1922												
Jan. 5	3	1	1	3	3	0	2	3	3	1	1	3
Jan. 25	4	1	2	2	4	0	0	5	4	0	5	0
Feb. 15	5	0	4	1	5	0	5	0	5	0	4	1
Mar. 6	6	0	5	0	6	0	2	3	6	0	2	3
Mar. 25	7	0	2	3	7	2	3	0	7	1	4	0
Apr. 15	8	0	1	4	8	0	3	2	8	1	3	1
May 5	9	5	0	0	9	2	0	3	9	2	1	2
Do	10	3	0	2	10	2	0	3	10	0	0	5
May 20	11	0	0	5	11	0	0	5	11	4	0	1
June 5	12	3	0	2	12	4	0	1	12	3	0	2
June 10	13	2	0	3	13	1	0	4	13	1	0	4
Do	14	2	0	3	14	0	0	5	14	3	0	2
Total		17	23	30		11	20	39		17	27	26

SPRING OF 1922

In view of the fact that depth of burial, within certain limits, made little or no difference in the activities of buried larvae, it was decided to cover larvae with 6 inches of soil in future experiments. This particular depth was chosen because most of the land under cultivation in the section surrounding Silver Creek is ordinarily plowed to this depth.

In conducting experiments during 1921, little consideration was given to the type of soil in which the infested material was buried, most of the work being done in shale loam. In the spring of 1922 three series of cylinder cages were started, one in gravelly loam, one in sandy loam, and a third in clay loam. Each series consisted of four cylinders, each of which contained 10 larvae buried to a depth of 6 inches. The cages were placed in the ground on April 8, 1922, and each one was supplied with uninfested cornstalk sections on the soil surface to act as a trap. The tops of the cages were covered with fine-mesh wire screening. The total migration in gravelly loam was 50 per cent, in sandy loam 40 per cent, and in heavy loam 42.5 per cent. (Table 2.) This experiment and others conducted during subsequent years indicated that soil type has little effect upon the activities of buried larvae, except that soil of a sandy nature tends to retard buried larvae in their efforts to reach the soil surface.

TABLE 2.—*Migration of corn-borer larvae (from three lots, 40 larvae per lot) buried 6 inches deep in various types of soil, Silver Creek, N. Y., 1922*

Date examined	Larvae at surface of gravelly loam [1]	Larvae at surface of sandy loam [1]	Larvae at surface of heavy loam [1]	Date examined	Larvae at surface of gravelly loam [1]	Larvae at surface of sandy loam [1]	Larvae at surface of heavy loam [1]
Apr. 10	0	0	0	May 8	0	2	2
Apr. 12	0	0	0	May 10	4	1	0
Apr. 14	0	0	1	May 12	1	2	1
Apr. 16	0	0	1	May 14	0	0	0
Apr. 18	0	0	1	May 16	0	0	0
Apr. 20	0	0	0	May 18	0	0	0
Apr. 22	0	0	1	May 20	0	0	0
Apr. 24	0	2	0	May 22	[2] 1	0	0
Apr. 26	0	3	4	May 24	0	1	0
Apr. 28	3	3	3				
Apr. 30	7	0	0	Total recovered at surface	20	16	17
May 2	0	0	0				
May 4	3	2	2	Percentage recovered at surface	50	40	42.5
May 6	1	0	1				

[1] Buried in gravelly loam Apr. 7, sandy loam Apr. 8, heavy loam Apr. 10.
[2] Dead; all others alive.

FALL OF 1922

In the fall of 1922 two series of burials were made using seven 3 by 5 foot pits in each series, one pit in each series being caged and the others left open. The series were started on September 20 and October 20, respectively. Approximately 25 larvae were placed in each burial of the first series, whereas only 20 were placed in each burial of the second series. At regular intervals during the fall of 1922 and spring of 1923 uncaged pits from each series were opened and examined for the presence of dead and living larvae in the soil and buried stalks. On each inspection date the two caged pits were inspected to determine the number of larvae in the paper traps and on the ground surface. All larvae found were removed and destroyed. In this way it was possible to determine on each inspection date the number of larvae which had reached the soil surface since the last examination of the traps. At the end of the experiment the two caged pits were opened and inspected. Table 3 shows the amount of migration from the two series of burials.

TABLE 3.—*Migration of corn-borer larvae buried in shale loam to a depth of 6 inches, Silver Creek, N. Y., 1922*

Series	Kind of pit	Date buried	Total larvae	Larvae migrating to surface—						Larvae dead below surface		Larvae alive below surface		Larvae missing	
				In fall		In spring		Total							
			No.	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
1	Open	Sept. 20	150							6	4	15	10	129	86
	Caged (check)	do	25	21	84	3	12	24	96	1	4	0	0	0	0
2	Open	Oct. 20	120							3	2.5	31	25.8	86	71.
	Caged (check)	do	20	3	15	8	40	11	55	2	10	2	10	5	25

Table 3 shows that the trap recoveries from the check cage of series 1 amounted to 96 per cent of the total larvae involved, as compared with 55 per cent in the check cage of series 2. This indicated a rather decided advantage in favor of the October plowing, but since the evidence was obtained from observations of a compara-

tively small number of larvae it could not be considered as conclusive. All the larvae in the check cage of series 1 were accounted for, whereas 25 per cent of the larvae in the check cage of series 2 were missing. It is probable that they died and disintegrated in the soil. The trap recoveries from the check cages indicated that most of the larvae recorded as missing from the open burials migrated to the surface and escaped. Previous experiments had indicated that late fall plowing resulted in slightly more larval mortality than plowing done in early fall, but generally the difference was much less noticeable than in this particular experiment. In general, the results indicated that the majority of early-buried larvae migrated to the surface during the fall, whereas larvae buried at a later date, when the soil temperature was lower, had a tendency to remain in the soil during the winter and migrate in the spring. The experiment did not indicate that time of plowing could be considered an important factor in the control of the borer.

In addition to the two series of burials in 3 by 5 foot pits in the fall of 1922, five series of cages of the smaller type, 15 by 18 inches, were placed in the ground. Four of these series contained 15 cages each, while the fifth, which was started on November 1, contained only 10. All cages were covered at top and bottom with 20-mesh copper screening, except the first one, which was covered with 16-mesh screening. This screening proved to be coarse enough to allow larvae to pass through, consequently the later series were equipped with 20-mesh wire. Cages from each series were opened and inspected each week during the fall of 1922 and spring of 1923. The results indicated that approximately 55 per cent of the larvae in the entire experiment reached the soil surface in the fall and that less than 2 per cent migrated in the spring. (Table 4.)

TABLE 4.—*Migration of buried corn-borer larvae as affected by time of burial, Silver Creek, N. Y., 1922*

Series	Date buried	Total larvae	Larvae migrating to surface—						Larvae dead below surface		Larvae alive below surface		Larvae missing	
			In fall		In spring		Total							
		No.	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
1	Aug. 15	300	43	14.3	2	0.7	45	15.0	10	3.3	8	2.7	237	79.0
2	Sept. 1	304	246	80.9	3	1.0	249	81.9	9	3.0	18	5.9	28	9.2
3	Sept. 15	305	238	78.0	9	3.0	247	81.0	12	3.9	34	11.2	12	3.9
4	Oct. 2	283	219	77.4	5	1.8	224	79.2	14	4.9	38	13.4	7	2.5
5	Nov. 1	182	20	11.0	4	2.2	24	13.2	58	31.9	89	48.9	11	6.0

The small number of larvae recovered on the surface of series 1 was probably caused by the loss of migrating larvae before the 20-mesh wire screening was applied to the tops of the cages. Since series 1 was the first to be placed in the ground, it is probable that there was more migration to the soil surface from this series than from any of the others, and many of these migrating larvae undoubtedly escaped through the 16-mesh screening. In general, the fall migration decreased directly with the lateness in the time of burial, the early burials resulting in the largest amount of fall migration. The late burials, however, produced the greatest amount of spring migration, indicating that larvae buried after September 15 have a tendency to remain in the soil during the winter.

SPRING OF 1923

On April 20, 1923, four box cages, 17 inches long, 14 inches wide, and 12 inches deep, covered at top and bottom with fine wire screening, were placed in shale loam, each cage holding 20 larvae contained in short stalk sections. In conducting previous burial experiments, longer stalk sections had been used, and no data had been obtained concerning the activities of larvae buried in sections from 1½ to 2 inches in length. One cage was opened every 10 days during the spring of 1923, the last inspection being on May 31. Of the 80 larvae buried, only 2 were found dead in the soil. Approximately 50 per cent migrated to the surface and were recovered in the traps, while more than 26 per cent had left the stalk sections and were working toward the soil surface. Six larvae were recovered above the soil surface from the first cage to be opened, whereas 14 were found on the surface of the last cage inspected. Approximately 20 per cent of the

FIGURE 1.—View showing five series of hand burials of corn-borer larvae in shale loam, Silver Creek, N. Y., 1923. Each series consisted of one caged burial and several open burials, the latter indicated by white stakes

total remained in the buried stalks. This experiment indicated that larvae buried in short stalk sections to a depth of 6 inches will migrate to the surface in great numbers.

FALL OF 1923

In the fall of 1923 five series of cages (fig. 1), each cage measuring 17 by 14 by 12 inches and each series containing 15 cages, except the last one to be started, which contained 13, were placed in shale loam to determine the amount of spring and fall migration of larvae buried on various dates during the fall. The five series contained a total of 1,420 larvae, of which 385, or 27 per cent, reached the soil surface, and 206, or 14 per cent, were found dead below the surface. Larvae buried on September 15 were recovered above the soil in large numbers shortly after being placed in the ground. The surface recoveries during the fall decreased in each of the other four series to 3.1 per cent in the last one, which was placed in the ground on November 15. The

spring recoveries, however, increased according to the time of burial, the recoveries being decidedly larger from the late-buried material than from that placed in the ground during September and October. This experiment verified the results of similar experiments conducted in previous years. The results appeared to be rather favorable to fall plowing as a control measure, but this apparent advantage was less noticeable in experiments conducted during previous years. The missing larvae probably died and disintegrated in the soil. This theory is strengthened by the fact that the number of missing larvae increased as the season progressed. The results are summarized in Table 5.

TABLE 5.—*Fall and spring migration of corn-borer larvae buried at various times in the fall, Silver Creek, N. Y., 1923*

Series	Date buried	Total larvae	Larvae migrating to surface—						Larvae dead below surface		Larvae alive below surface		Larvae missing	
			In fall		In spring		Total							
		No.	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
1	Sept. 15	280	144	51.4	0	0	144	51.4	20	7.1	73	26.1	43	15.4
2	Oct. 1	300	115	38.3	1	.3	116	38.7	41	13.7	91	30.3	52	17.3
3	Oct. 15	280	74	26.4	1	.4	75	26.8	32	11.4	115	41.1	58	20.7
4	Nov. 1	300	8	2.7	23	7.7	31	10.3	58	19.3	141	47.0	70	23.3
5	Nov. 15	260	8	3.1	11	4.2	19	7.3	55	21.2	117	45.0	69	26.5

In addition to the experiment described, a second project was conducted in the fall of 1923, consisting of six series of burials, each series containing nine open pits and one check cage, each measuring 60 by 36 by 12 inches. The check cages were covered with 20-mesh screen and equipped with corrugated-paper traps. The open pits adjoined the check cages but were not equipped with traps, and any larvae which reached the surface were free to migrate at will. Each burial contained 18 cornstalks averaging 1.4 larvae per stalk, or approximately 25 larvae. The stalks were buried to a depth of 6 inches. The first series was placed in the ground on September 20, and the others followed at 10-day intervals until November 10, when the last series was buried. At 10-day intervals during the fall of 1923 and spring of 1924, one uncaged burial from each series was opened and inspected, records being made of the number of dead and living larvae found in the buried stalks and in the surrounding soil. On each inspection date observations were made in the six check cages to determine the number of larvae that had reached the soil surface during the previous 10-day period. In this way information was obtained from the open burials concerning the number of larvae in the soil on the various inspection dates, and data were obtained from the check cages which indicated the number of larvae which had reached the soil surface since the previous examination.

Inasmuch as the open burials were not equipped with traps, it was impossible to obtain data from them which would indicate the number of larvae reaching the soil surface. This information, however, was obtained from the six check cages in which were buried 157 larvae. Of this total, 107, or 68.2 per cent, reached the soil surface during the fall and spring. This ratio, 68.2 per cent, may be applied to the open burials in estimating the number of larvae which migrated from them to the surface. Comparatively few dead larvae were

found below the soil surface. A total of 142 living larvae were recovered from the caged and uncaged burials after April 7, 1924. Practically all were recovered from the series placed in the ground late in the fall while the soil temperature was low enough to retard larval activity. In other words, the experiment indicated that larvae buried in September and early October come to the surface within a comparatively short time, but that those buried in November usually remain in the soil and either perish during the winter or migrate in the spring. The results of this experiment are summarized in Table 6.

TABLE 6.—*Migration of corn-borer larvae buried in the fall in open and caged pits, Silver Creek, N. Y., 1923*

Series	Kind of pit	Date buried	Total larvae	Larvae migrating to surface—						Larvae dead below surface		Larvae alive below surface		Larvae missing	
				In fall		In spring		Total							
			No.	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
1	Open	Sept. 20	225							2	0.9	42	18.7	181	80.4
	Caged (check)	do	25	9	36	0	0	9	36	0	0	0	0	16	64.0
2	Open	Sept. 30	225							4	1.8	35	15.6	186	82.7
	Caged (check)	do	25	19	76	3	12	22	88	0	0	0	0	3	12.0
3	Open	Oct. 10	225							5	2.2	63	28.0	157	69.8
	Caged (check)	do	25	6	24	6	24	12	48	0	0	0	0	13	52.0
4	Open	Oct. 20	225							5	2.2	84	37.3	136	60.4
	Caged (check)	do	25	1	4	11	44	12	48	0	0	0	0	13	52.0
5	Open	Oct. 30	225							6	2.7	82	36.4	137	60.9
	Caged (check)	do	32	4	12.5	27	84.3	31	96.8	1	3.1	0	0	0	0
6	Open	Nov. 10	225							20	8.9	50	22.2	155	68.9
	Caged (check)	do	25	0	0	21	84	21	84	0	0	0	0	4	16.0

During the course of this experiment the temperature of shale loam at a depth of 6 inches was recorded by means of a thermograph. Migration to the surface had practically ceased by October 30, and at that time the soil temperature was approximately 44° F. November 10 was the last date on which fall-migrating larvae were found on the soil surface. At that time the soil temperature was approximately 36° F. This indicated that there was very little larval activity in this type of soil after the soil temperature reached 36° F.

SPRING OF 1924

In order to determine more accurately the amount and rate of migration from burials in various types of soil on several dates, three series of burials were conducted in the spring of 1924, in clay, sand, and loam, respectively. Each series was divided into four groups, the original plan being to place one group from each series in the ground on each of several dates. Because of the amount of labor involved it was impossible to bury a group from each series in a single day, and for that reason the first group from the loam series was buried on April 15, but the first groups from the clay and sand series were delayed until April 22. Additional groups from the loam series were placed in the ground on April 25, May 5, and May 15, while the remaining groups in the clay and sand series were buried on May 2, May 12, and May 22. The first group in each series was composed of six open pits adjoining one check cage, 60 by 36 by 12 inches in size. The check cage was covered with fine-mesh wire screening and equipped with a corrugated-paper trap. Each

pit contained 25 cornstalks, averaging one larva per stalk, or 25 larvae per burial. In each of the subsequent groups of each series the number of burials was reduced by one, in order that the examination of all groups might be completed on or about June 1, when pupation usually begins.

One open burial from each group was taken up every 10 days and inspected for the presence of dead and living larvae in the buried stalks and surrounding soil. The check cages were inspected at the same time, and records were made of the number of larvae found in the traps and on the soil surface. All larvae reaching the soil surface from the open burials were free to migrate in any direction, and for that reason it was impossible to learn how many larvae actually reached the surface and escaped. By making accurate observations in each check cage, however, this number could be obtained and applied to the burials which were not equipped with traps. At the end of the experiment the check cages were removed and examined carefully for dead and living larvae in the soil and buried stalks. Comparatively few dead larvae were found in any of the series, and the number alive below the surface of the ground at the end of the experiment indicated that most of the larvae, with the exception of those confined by traps, found their way to the soil surface and escaped. The results strengthened previous conclusions that soil type had little effect upon the number of larvae that migrated to the soil surface, since approximately 80 per cent of the buried larvae were recovered on the surface of each soil type. The time of burial had little effect upon migration, except that the early-buried larvae were slower in migrating than those buried later in the spring.

PLOWING EXPERIMENTS

NECESSITY OF SIMULATING FIELD CONDITIONS

Inasmuch as the information gained from the hand burials was obtained under extremely unnatural conditions, as previously related, it was evident that control recommendations could not be based entirely upon such evidence. The study of the behavior of the insect under these artificial conditions was justified, however, because it enabled the authors to obtain certain significant facts concerning the activities of buried larvae which could not have been obtained from experiments conducted under more natural conditions. The cages in which the hand burials were made doubtless interfered with the activities of the buried larvae, but without the cages it would have been impossible to obtain accurate information concerning the number of larvae that reached the soil surface. It was possible to sift and thoroughly examine the soil used in the hand burials, and thus obtain information about the larvae which were not recovered in the traps. However, the results obtained from these small cage experiments gave little or no information regarding the probable activities of larvae after reaching the soil surface in an open cornfield. The screen tops attached to the cages excluded all birds and many insects which might otherwise have destroyed many of the larvae on the surface of the soil.

The hand burials were intended, primarily, to furnish information concerning the subterranean activities of larvae rather than their activities on the soil surface. After this information was obtained

from the hand burials, it became necessary to conduct plowing experiments in order to trace as closely as possible the movements of the larvae after reaching the surface. Traps were used in the plowing experiments, but the areas involved were larger than those of the hand burials, and larvae, upon reaching the surface, were obliged to travel farther in order to reach the corrugated-paper traps. The plowed areas were not covered with screening, and birds were allowed free access to them. These experiments were begun in the fall of 1923 and were continued over a period ended in the spring of 1927. In general, the procedure followed was the same in all these experiments, although various changes were made in the construction and size of the traps used. (Fig. 2.)

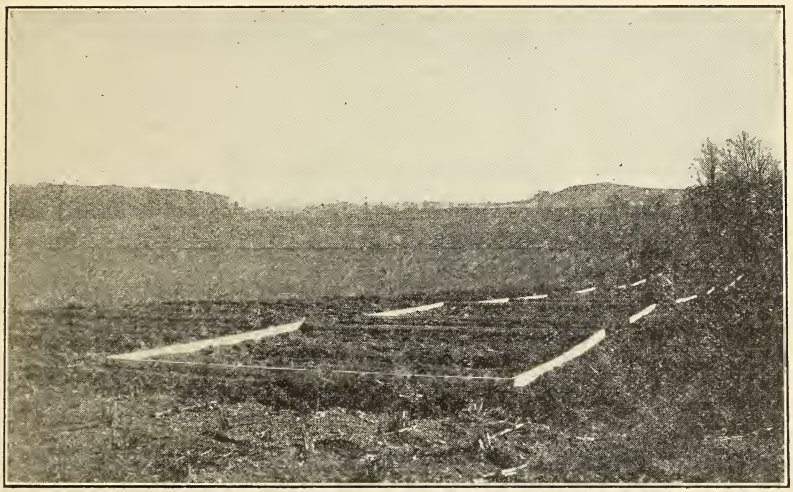

FIGURE 2.—Type of trap used in the early plowing experiments, Silver Creek, N. Y., 1922. The principle of this trap was used in later experiments, although changes were made in its construction from time to time

DESCRIPTION OF TRAPS USED IN EXPERIMENTS

The recovery traps used in the early plowing experiments consisted of four yellow-pine boards, 4 inches wide and seven-eighths of an inch thick, nailed together tightly at the corners to form a square, and placed on edge in the ground to a depth of 1 inch. Much of the lumber used was of poor quality and it was necessary to cover many checks and knot holes with 20-mesh wire screening. Split laths were nailed to both sides of the trap, parallel with, and 1 inch below the tops of the boards, space being left between the laths and the boards to admit the insertion of strips of double-corrugated strawboard, 1 inch wide, having the corrugations in a vertical position. The strawboard rested on the wire brads or finish nails which were used in fastening the laths to the boards, and it could be easily removed for inspection or replacement. In order to protect the strawboard from rain and cause it to afford better hibernating conditions for migrating larvae, yellow-pine boards, 3 inches wide and seven-eighths of an inch thick, were fastened horizontal and parallel with the full length of the trap in such a manner that the overhang of the 3-inch boards protected the strawboard strips from the sun and rain. These protective boards were

fastened lightly and could be easily removed when the trap was inspected. The strawboard on the inside of the trap provided shelter for any larvae which might migrate to it from the buried material, while the strawboard sections fastened to the outside of the trap served as a barrier to larvae which might attempt to pass over the trap and enter the area used in the experiment.

The principle of the trap described above was used in conducting all plowing experiments, although it became advisable at various times to make certain changes in the size and quality of the materials used in constructing the trap. Shortly after the experiments were started, the 4-inch boards were replaced by 6-inch boards which were placed in the ground to a depth of 3 inches. Heavy rains washed soil away from the 4-inch boards, leaving passages under them through which larvae could escape. The 6-inch boards were later found to be objectionable for the same reason, and it was necessary to replace them with boards 12 inches wide and seven-eighths of an inch thick. The 3-inch protective boards served very well in shielding the strawboard from the rain and sun, but it was found that a small number of larvae passed through the corrugations of the strawboard and crawled over the tops of the traps and escaped. For this reason the protective boards were discarded and replaced by 9-inch strips of white oilcloth, attached horizontally to the tops of the 12-inch boards and overhanging both sides of the trap, with the smooth side of the oilcloth downward. The oilcloth was held in position on top of the 12-inch boards by slender strips of wood, three-fourths of an inch wide and one-fourth of an inch thick, which were nailed to the tops of the 12-inch boards with small brads.[2] The oilcloth was held almost horizontally, but at a slightly downward angle, by means of sections of spring wire above and below the oilcloth. The sections of spring wire protruded beyond the edges of the oilcloth, and the ends were bent into loops which were used in holding the wires together. In this way the oilcloth was held firmly, and damage by wind was reduced to a minimum. The ends of the oilcloth strips were sewed together tightly at the corners of the trap in order that the oilcloth might be kept tight and be held in position by the wires. By sliding back the upper sections of wire and lifting the oilcloth, the strawboard sections could be easily examined. (Fig. 3.)

DISCUSSION OF EXPERIMENTS

In order to record in detail the results of the examinations made in the traps and soil of the various plowing experiments, it was necessary to construct rather large tabular forms, which the writers believe need not be included in this bulletin. The information has been summarized in Tables 7 and 8, one dealing with those experiments which were started in the spring and the other containing results of experiments started in the fall. The information in Table 7 was obtained during the period from 1924 to 1927, inclusive, whereas Table 8 covers the years from 1923 to 1926, inclusive.

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[2] WORTHLEY, L. H., and CAFFREY, D. J. SCOUTING, QUARANTINE, AND CONTROL FOR THE EUROPEAN CORN BORER, 1917–1926. U. S. Dept. Agr. Tech. Bul. 53, p. 67. 1927.

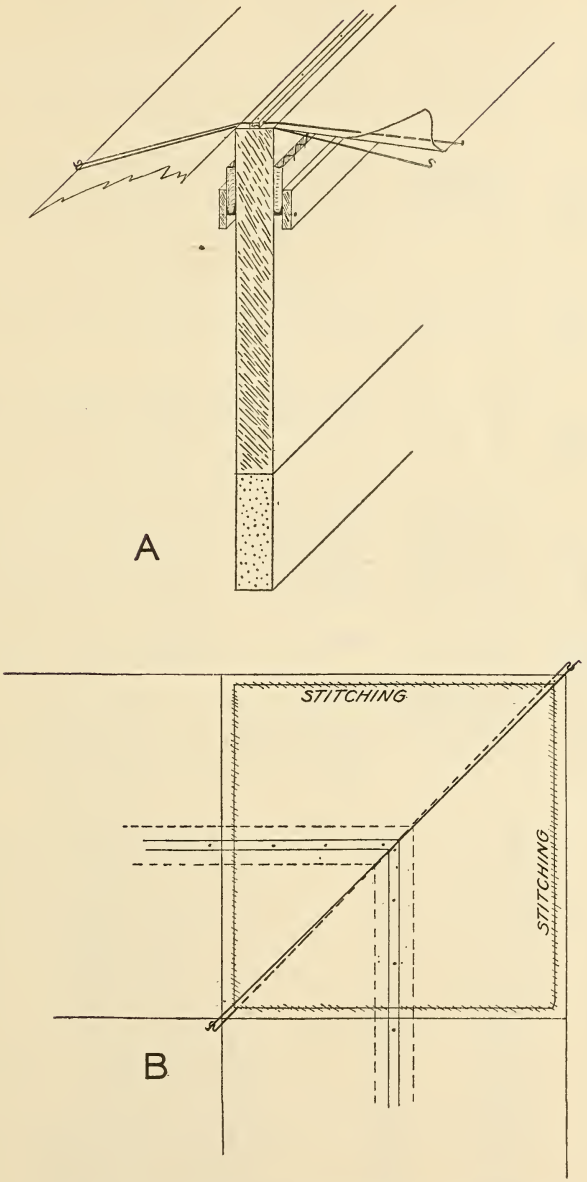

FIGURE 3.—A, Construction details of trap used in plowing experiments; B, details of oilcloth strips sewed tightly at the corners to avoid damage by wind

TABLE 7.—*Results of spring plowing experiments conducted at Silver Creek, N. Y., 1924 to 1927*

Experiment No.	Description of experiment	Lot No.	Date experiment started	Estimated larvae in experiment	Recoveries of living larvae and pupae—								Total dead larvae or pupae		Total larvae not recovered	
					In recovery trap		On soil surface		Below soil surface		Total recoveries					
			1924	*No.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
1	Spring plowing, 1924: Plowed area, 16 by 16 feet, recovery trap adjacent; no débris on surface	1	Apr. 15	28	19	67.8	0	0	0	0	19	67.8	0	0	9	32.2
2	do	2	Apr. 22	28	27	96.4	0	0	0	0	27	96.4	0	0	1	3.6
3	do	3	Apr. 29	28	15	53.6	0	0	0	0	15	53.6	0	0	13	46.4
4	do	4	May 6	31	31	100.0	0	0	0	0	31	100.0	0	0	00	00
5	do	5	May 13	29	29	100.0	0	0	0	0	29	100.0	0	0	00	00
6	do	6	May 20	28	20	71.4	0	0	0	0	20	71.4	0	0	8	28.6
			1925													
7	Spring plowing, 1925: Plowed area, 16 by 16 feet, recovery trap adjacent; no débris on surface	1	Apr. 7	40	29	72.5	1	2.5	1	2.5	31	77.5	0	0	9	22.5
8	do	2a	Apr. 14	40	25	62.5	2	5.0	0	0	27	67.5	2	5.0	11	27.5
9	do	2b	do	40	28	70.0	0	0	0	0	28	70.0	1	2.5	11	27.5
10	do	3	Apr. 21	40	27	67.5	0	0	0	0	27	67.5	0	0	13	32.5
11	do	4	Apr. 28	40	18	45.0	5	12.5	2	5.0	25	62.5	1	2.5	14	35.0
12	do	5	May 5	40	22	55.0	0	0	1	2.5	23	57.5	0	0	17	42.5
13	do	6	May 12	40	14	35.0	2	5.0	0	0	16	40.0	1	2.5	23	57.5
			1926													
14	Spring plowing, 1926: Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface	1a	Apr. 21	100	57	57.0	0	0	0	0	57	57.0	0	0	43	43.0
15	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface	1b	do	200	17	8.5	3	1.5	2	1.0	22	11.0	0	0	178	89.0
16	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet of débris per square rod	1c	do	200	13	6.5	52	26.0	0	0	65	32.5	0	0	135	67.5
17	Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface	2a	May 10	83	56	67.4	0	0	0	0	56	67.4	0	0	27	32.6
18	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface, land disked	2b	do	200	12	6.0	7	3.5	1	.5	20	10.0	0	0	180	90.0
19	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet of débris per square rod	2c	do	200	9	4.5	57	28.5	0	0	66	33.0	2	1.0	132	66.0
			1927													
20	Spring plowing, 1927: Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface	1a	Apr. 11	200	156	78.0	1	.5	1	.5	158	79.0	4	2.0	38	19.0
21	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface	1b	do	500	60	12.0	8	1.6	2	.4	70	14.0	29	5.8	401	80.2
22	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet of débris per square rod	1c	do	500	28	5.6	52	10.4	0	0	80	16.0	24	4.8	396	79.2
23	Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface	2a	May 10	200	161	80.5	0	0	0	0	161	80.5	8	4.0	31	15.5

24	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface	2b	...do....	500	38	7.6	18	3.6	4	.8	60	12.0	34	6.8	406	81.2
25	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet of débris per square rod	2c	...do....	500	9	1.8	34	6.8	0	0	43	8.6	39	7.8	418	83.6
	Total			3,835	920		242		14		1,176		145		2,514	
	Average					24.0		6.3		.4		30.7		3.8		65.6
	Summary:															
	Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface			583	430	73.8	1	.2	1	.2	432	74.1	12	2.1	139	23.8
	Plowed area, 16 by 16 feet, recovery trap adjacent; no débris on surface			452	304	67.3	10	2.2	4	.9	318	70.4	5	1.1	129	28.5
	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface			1,400	127	9.1	36	2.6	9	.6	172	12.3	63	4.5	1,165	83.2
	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet of débris per square rod			1,400	59	4.2	195	13.9	0	0	254	18.1	65	4.6	1,081	77.2
	Total			3,835	920		242		14		1,176		145		2,514	
	Average					24.0		6.3		.4		30.7		3.8		65.6

TABLE 8.—*Results of fall plowing experiments conducted at Silver Creek, N. Y., 1923 to 1926*

Experiment No.	Description of experiment	Lot No.	Date experiment started	Estimated larvae in experiment	Recoveries of living larvae and pupae—								Total dead larvae or pupae		Total larvae not recovered	
					In recovery trap		On soil surface		Below soil surface		Total recoveries					
1	Fall plowing, 1923: Plowed area, 14 by 14 feet, recovery trap adjacent; no débris on surface		1923	*No.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*	*No.*	*P. ct.*
		1	Sept. 29	31	10	32.3	0	0	0	0	10	32.3	0	0	21	67.7
2	----do----	2	Oct. 6	49	27	55.1	0	0	0	0	27	55.1	0	0	22	44.9
3	----do----	3	Oct. 13	40	28	70.0	0	0	0	0	28	70.0	0	0	12	30.0
4	----do----	4	Oct. 20	36	25	69.4	0	0	0	0	25	69.4	0	0	11	30.6
5	----do----	5	Oct. 27	59	10	16.9	0	0	0	0	10	16.9	0	0	49	83.1
6	----do----	6	Nov. 3	39	20	51.3	0	0	0	0	20	51.3	0	0	19	48.7
7	----do----	7	Nov. 11	42	26	61.9	0	0	0	0	26	61.9	0	0	16	38.1
8	Fall plowing, 1924: Plowed area, 16 by 16 feet, recovery trap adjacent; no débris on surface		1924													
		1	Sept. 20	40	18	45.0	0	0	0	0	18	45.0	0	0	22	55.0
9	----do----	2	Sept. 27	37	27	73.0	0	0	0	0	27	73.0	0	0	10	27.0
10	----do----	3	Oct. 6	34	17	50.0	0	0	2	5.9	19	55.9	0	0	15	44.1
11	----do----	4	Oct. 11	37	31	83.8	0	0	4	10.8	35	94.6	0	0	2	5.4
12	----do----	5	Oct. 18	49	45	91.8	0	0	2	4.1	47	95.9	2	4.1	0	0
13	----do----	6	Oct. 25	32	26	81.3	0	0	0	0	26	81.3	0	0	6	18.7
14	----do----	7	Nov. 1	37	35	94.6	0	0	0	0	35	94.6	2	5.4	0	0
15	----do----	8	Nov. 8	30	19	63.3	0	0	0	0	19	63.3	0	0	11	36.7
16	----do----	9	Nov. 15	24	18	75.0	0	0	3	12.5	21	87.5	0	0	3	12.5
17	----do----	10	Nov. 22	21	16	76.2	0	0	1	4.8	17	81.0	1	4.7	3	14.3
	Fall plowing, 1925:															
18	Plowed area, 16 by 16 feet, recovery trap adjacent; no débris on surface		1925													
		1	Sept. 20	100	63	63.0	2	2	0	0	65	65.0	0	0	35	35.0
19	----do----	2	Oct. 1	100	78	78.0	14	14	0	0	92	92.0	0	0	8	8.0
20	----do----	3a	Oct. 13	100	25	25.0	8	8	0	0	33	33.0	1	1.0	66	66.0
21	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface	3b	---do----	1,000	39	3.9	45	4.5	0	0	84	8.4	3	.3	913	91.3
22	Plowed area, 16 by 16 feet, recovery trap adjacent; no débris on surface	4a	Nov. 2	100	42	42.0	7	7	0	0	49	49.0	0	0	51	51.0
23	Plowed area, 16 by 16 feet, recovery trap adjacent; 30 linear feet of débris per square rod	4b	---do----	100	13	13.0	15	15	0	0	28	28.0	0	0	72	72.0
	Fall plowing, 1926:															
24	Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface		1926													
		1a	Oct. 15	100	10	10.0	0	0	0	0	10	10.0	14	14.0	76	76.0
25	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface	1b	---do----	1,000	79	7.9	36	3.6	1	.1	116	11.6	26	2.6	858	85.8

26	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet of débris per square rod	1c	---do----	1,000	73	7.3	47	4.7	0	0	120	12.0	24	2.4	856	85.6
27	Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface	2a	Nov. 11	100	22	22.0	0	0	0	0	22	22.0	7	7.0	71	71.0
28	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface	2b	---do----	1,000	40	4.0	32	3.2	0	0	72	7.2	6	.6	922	92.2
29	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet of débris per square rod	2c	---do----	1,000	53	5.3	33	3.3	1	.1	87	8.7	10	1.0	903	90.3
	Total			6,337	935		239		14		1,188		96		5,053	
	Average					14.8		3.8		.2		18.8		1.5		79.7
	Summary:															
	Hand buried in 40 by 40 inch area, recovery trap adjacent; no débris on surface			200	32	16.0	0	0	0	0	32	16.0	21	10.5	147	73.5
	Plowed area, 14 by 14 feet, recovery trap adjacent; no débris on surface			296	146	49.3	0	0	0	0	146	49.3	0	0	150	50.7
	Plowed area, 16 by 16 feet, recovery trap adjacent; no débris on surface			741	460	62.1	31	4.2	12	1.6	503	67.9	6	.8	232	31.3
	Plowed area, 16 by 16 feet, recovery trap adjacent; 30 linear feet of débris per square rod			100	13	13.0	15	15.0	0	0	28	28.0	0	0	72	72.0
	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; no débris on surface			3,000	158	5.3	113	3.8	1	.03	272	9.1	35	1.2	2,693	89.7
	Plowed area, 16 by 16 feet, recovery trap 12½ feet distant; 30 linear feet feet of débris per square rod			2,000	126	6.3	80	4.0	1	.05	207	10.3	34	1.7	1,759	88.0
	Total			6,337	935		239		14		1,188		96		5,053	
	Average					14.8		3.8		.2		18.8		1.5		79.7

A study of Tables 7 and 8 shows that several factors were considered in conducting the experiments. Determining the number of larvae which actually reached the surface was a comparatively simple matter, but it was necessary, in order to formulate any practical control measures, to obtain definite information concerning the fate of larvae after they reached the soil surface. With no surface débris present, it appeared reasonable that a greater number of larvae would be killed on the soil surface by birds, insects, and the sun. However, if sections of cornstalks or other plant remnants were left on the surface to afford shelter, it appeared probable that migrating larvae might enter such sections and thereby receive protection from other insects and the elements.

It was apparent that the location of the trap would be a very important factor in determining the fate of larvae after reaching the soil surface. When the trap was placed immediately adjacent to the place of burial, the migrating larvae were required to travel a very short distance in order to find shelter in the sections of strawboard. In order to determine the amount of protection afforded to migrating larvae by traps placed adjacent to the places of burial, certain experiments were conducted in which traps were placed 12½ feet from the actual places of burial.

Approximately 24 per cent of the larvae in the spring experiments were recovered in the traps, whereas 15 per cent of the larvae were recovered in the traps placed in the ground in the fall. The lower soil temperature encountered by larvae plowed under in the fall tended to decrease their activities, and many of them, therefore, remained in the stalks and there perished during the winter. Larvae plowed under in spring, however, encountered warmer temperatures, which resulted in greater larval activity. The recoveries of living larvae on the soil surface amounted to 6.3 per cent in the spring experiments and 3.8 per cent in the experiments started in the fall. As in the case of trap recoveries, the larger number of larvae recovered on the soil surface in the spring experiments was the result of higher soil temperature. The number of living larvae recovered below the soil surface was so small in both types of experiments as to be of little significance. Such larvae were recovered by means of sifting soil from the surface of the various experiments and by digging up and dissecting the buried stalks.

The number of dead larvae recovered from the spring experiments amounted to 3.8 per cent of the larvae plowed under in the spring whereas the corresponding figure for the fall plowings was 1.5 per cent. Most of the dead larvae recovered below the surface of the spring plowings were intact and were found with much less difficulty than similar larvae in the fall plowings. In the latter group of experiments it was not unusual to find badly decomposed individuals below the surface, and there is little doubt that many larvae plowed under in the fall died and disintegrated in the soil.

With the exception of the small check cages, the largest trap recoveries were made from experiments in which the traps were close to the plowings, on the surface of which no débris was placed. It was apparent that the traps afforded protection which would not be available to larvae migrating from plowed-under material in an open field, and in order to determine the importance of the protection offered by the traps, another group of experiments was conducted under con-

ditions similar to those in the first group, except that the traps were placed at a distance of 12½ feet from the places of burial. (Fig. 4.) Under these conditions the trap recoveries in the spring experiments dropped from 68 to 9 per cent, and in the fall plowings from 63 to 5.3 per cent. The decided decrease in trap recoveries when the traps were placed at a distance of 12½ feet indicated very strongly that many larvae were destroyed by birds or the elements while attempting to reach débris or other protective material. A third group of experiments were similar to the second group except that uninfested cornstalks were placed on the plowed surface at the rate of 30 linear feet per square rod. The addition of this material to the surface of the burial plats caused a slight reduction in the trap recoveries in the spring experiments and a slight increase in the fall experiments. The surface recoveries, however, when débris was added to the soil sur-

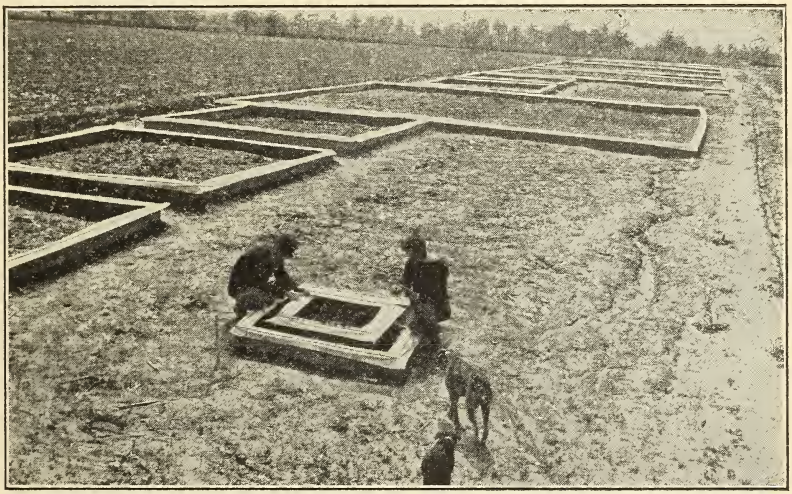

FIGURE 4.—Traps used in plowing experiments, Silver Creek, N. Y., 1926. Some of the traps were located adjacent to the plowed areas, while the larger ones were 12½ feet from the areas in which the infested material was plowed. The trap in the foreground is a test trap

face, increased from 3.8 to 4 per cent in the fall experiments, and from 2.6 to 13.9 per cent in the spring experiments.

In order to test the efficiency of the type of trap used in the experiments, a double trap was built which consisted of one complete trap, 40 inches square, constructed within another 55 inches square. (Fig. 5.) One hundred larvae were buried to a depth of 6 inches within the inner trap, and daily inspections were made of the two traps for the presence of migrating larvae. Many larvae were recovered in the inner trap, but none were found in the second or outer trap. The same results were obtained from a similar test conducted at Toledo, Ohio, by D. J. Caffrey.[3]

In general, no marked difference in effectiveness was indicated between spring plowing and fall plowing. In the experiments started in the fall approximately 80 per cent of the buried larvae were not recovered, while experiments conducted entirely in the spring resulted

[3] WORTHLEY, L. H., and CAFFREY, D. J. Op. cit., p. 67.

in the loss of 65 per cent of the larvae. Apparently fall plowing was somewhat more effective than spring plowing, although the difference was not great enough to warrant the recommendation that plowing be done at any particular time. Fall plowing is favored by some because it may result in greater larval mortality than spring plowing, but fall-plowed stubble may be brought to the surface by frost and heavy rains during the winter and spring and furnish protection for migrating larvae.

DISTANCE OF LARVAL MIGRATION

The efficiency of the traps used in the plowing experiments had been definitely established at Silver Creek, N. Y., and at Toledo, Ohio, and experiments conducted at both of these places[4] furnished conclusive evidence that recoveries in the traps decreased as the distance between the traps and the places of burial was increased. The

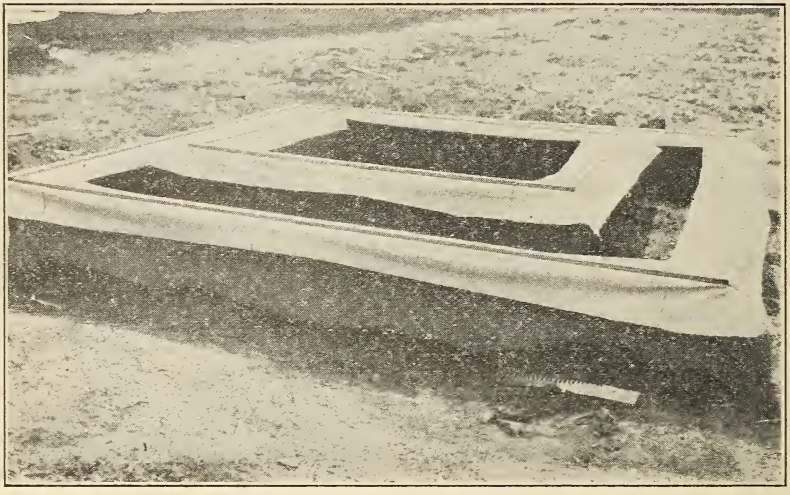

FIGURE 5.—Test trap constructed to determine the efficiency of the traps used in the plowing experiments. One hundred larvae were buried to a depth of 6 inches within the inner trap. Many migrating larvae were recovered in the inner trap, but none reached the outer one

results of these experiments did not, however, indicate the greatest distance migrating larvae would travel to reach suitable material in which to hibernate. In order to obtain this information, a special test was made at Silver Creek during the spring of 1925 which involved the burial in the soil of 1,000 corn-borer larvae to a depth of 6 inches. The experiment was conducted in sandy-loam soil which had been plowed the previous fall. All surface débris was removed, and a hole, 18 inches in diameter and 6 inches deep, was dug at a point approximately in the center of the field. In order to concentrate the 1,000 larvae, it was necessary to distribute them among short sections of uninfested cornstalks which had been placed at the bottom of the hole. The hole was then filled with earth to the level of the surrounding soil. Naturally infested cornstalks would have been preferable, but if such material had been used it would have been necessary to bury at least 100 stalks to obtain the desired number of larvae. This

[4] WORTHLEY, L. H., and CAFFREY, D. J. Op. cit., p. 67.

amount of material would have required an excavation much larger than the one used, and it would have been impossible to tell whether larvae migrated from the center or the outer edge of the burial.

In order to determine the rapidity and distance of larval migration, a trap was placed 15 feet from the center of the burial. This trap consisted of several 14-foot sections placed in a broken circle around the burial. Each section of trap consisted of a board, 14 feet long by 5 inches wide, to the sides of which double-corrugated strawboard was tacked. The experiment was started on April 5, and the traps were examined daily until April 17, when one larva was recovered. On April 17 the traps were removed and placed at a distance of 20 feet, where one larva was recovered on April 27. On this date the

FIGURE 6.—Many larvae are destroyed by cleanly plowing under cornstalks and stubble. When the work is well done there is usually very little surface débris to be collected and destroyed after the land has been completely prepared for planting

traps were removed to a distance of 30 feet, and a recovery was made on May 15. No recoveries were made at a distance greater than 30 feet from the burial.

RELATION OF CULTURAL PRACTICES TO CONTROL

In order to substantiate the information obtained from purely experimental work on the effectiveness of plowing and burying as a means of controlling the European corn borer, it seemed advisable to conduct observations in commercial fields where various methods had been used in preparing land for planting. The usual procedure in western New York consists of fall plowing of corn stubble, followed by disk or spring-tooth harrowing in the spring. Some farmers, however, prefer to plow the whole stalks under in the fall, while others wait until spring to plow standing stalks or stubble. (Fig. 6.)

In choosing fields in which to make observations the selections were made at random, with the exception of certain fields chosen for the examinations of 1927, in which special burning operations had been conducted in connection with the clean-up campaign carried on by the Bureau of Entomology during the spring of that year. The equipment used in burning stubble and stalks on the surface of cornfields is described fully by Caffrey and Worthley.[5] Two types of portable burners were used, one having 13 nozzles mounted on a 2-wheeled carriage and the other a hand burner equipped with three nozzles. The hand type was used in burning hedgerows, garden patches, etc., which could not be conveniently treated by the large carriage burners. The condition of these fields as a result of these operations is described hereafter.

The preliminary examinations in the fields consisted of estimating, as accurately as possible, the number of borers remaining in each field after the crop had been harvested. In making examinations to determine the number of larvae in corn stubble, an average of 100 stubs per acre were examined in each field under observation, the maximum examined in any one field being 500 stubs. An equal number of consecutive stubs were selected in the center of each quarter and in the center of the field. The first stub in each quarter was taken at random, and all the stubs to be examined in that section were taken consecutively in the same row.

The final examinations were made in the spring after the fields were ready for planting or had been planted, and consisted of the dissection and examination of all plant débris from the surface of 5 square rods in each field, 1 square rod in the center of the field, and 1 square rod in the center of each quarter of the field.[6] On the basis of the examinations in 5 square rods, the larval population of the entire field was computed. It was then possible to compare this figure with the larval population of the field before plowing. When the spring observations were made, information was obtained from the various growers concerning the time of plowing, kind of harrowing, etc., and the fields were grouped according to the treatment received in preparing them for planting.

IN 1926

The observations for 1926 were conducted in only six fields, and it seemed impractical to attempt to group this small number according to the methods employed in preparing them for planting. In Table 9, however, the treatment received by each field is specified. In general, slightly larger reductions of infestation occurred in fields from which the stalks had been removed before plowing, although the greatest reduction was found in field 1, where the entire stalks were plowed under. The owner of this field is more efficient than the average farmer in fitting his land, and the small survival of borers in his field was, undoubtedly, a direct result of the thoroughness with which the work was done. In the spring of 1926 deep trenches were plowed in field 6, causing many stalks to be brought to the surface, where they were allowed to remain. Many migrating larvae found these exposed stalks and crawled into them.

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[5] Worthley, L. H., and Caffrey, D. J. Op. cit., p. 45–50.
[6] Worthley, L. H., and Caffrey, D. J. Op. cit., p. 76.

TABLE 9.—*Record of examinations of débris made in commercial plantings of corn, Silver Creek, N. Y., 1926*

Field No.	Area	Treatment	Borers per acre before treatment	Borers per acre after treatment	Reduction	Date of final examination
	Acres		*Number*	*Number*	*Per cent*	
1	11	Stalks poled and field plowed in fall, disked in spring	10,578	64	99.4	May 28
2	4.5	Stalks cut and field plowed in fall, disked in spring	20,803	544	97.4	June 18
3	1.5	do	13,608	352	97.4	June 22
4	5	do	31,099	832	97.3	May 28
5	6	Stalks poled and field plowed in fall, disked in spring	13,512	544	95.9	June 18
6	.5	do	6,160	256	95.8	June 24

IN 1927

The observations for 1927 were conducted in 40 fields in which a variety of methods had been employed in preparing the land for planting. Some had been burned over by special burning equipment used by the Bureau of Entomology in its clean-up campaign conducted in the spring of 1927. Both fall and spring plowing were represented, and in some cases the usual methods of fitting land had been supplemented by the collecting of plant débris on the soil surface after the land had been made ready for planting. The 40 fields were divided into 12 classes, according to the treatment received in fitting them for planting, and records were made of the apparent survival of larvae under the various conditions existing in the several classes. The two fields representing class 6 were extremely wet, and it was impossible to plow them before the usual time for adult emergence. Mud in these fields was approximately 1 foot deep, and the burners were operated with great difficulty even when 15 men were used in drawing each burner. The infested stalks were saturated with water, and it was necessary that the flame be in direct contact with them for several seconds in order to destroy all infestation. Owing to the mud and the unevenness of the land, the burners could not be drawn steadily enough to apply sufficient heat to all stalks. Classes 8 and 10 are represented by abandoned cornfields which were so situated as to be reached with great difficulty by motor vehicles. The stubble in these fields was burned with oil applied by means of buckets and hand sprayers. These fields were not plowed.

The following classification applies to the fields examined in 1927, 1928, and 1929:

Class 1. Stalks cut in fall, spring plowed, hand picked.
Class 2. Stalks cut in fall, spring plowed, not hand picked.
Class 3. Whole stalks plowed in spring, hand picked.
Class 4. Whole stalks plowed in spring, not hand picked.
Class 5. Whole stalks plowed in fall, not hand picked.
Class 6. Whole stalks burned by carriage burner in spring, not hand picked.
Class 7. Whole stalks pulled and burned.
Class 8. Stalks cut in fall, stubble pulled and burned in spring.
Class 9. Stalks cut in fall, burned in piles, spring plowed, not hand picked.
Class 10. Stalks cut in fall, stubble burned by hand burners.
Class 11. Stalks cut in fall, stubble burned, hand picked.
Class 12. Stalks cut in fall, stubble disked, hand picked.
Class 13. Stalks cut in fall, fall plowed, hand picked.
Class 14. Stalks cut in fall, fall plowed, not hand picked.

TABLE 10.—*Record of examinations of débris made in commercial plantings of corn, Silver Creek, N. Y., 1927*

Classification of fields according to treatment	Number of fields examined	Total area in fields	Average number of borers per acre		Reduction in average number of borers per acre
			Before treatment	After treatment	
		Acres			*Per cent*
Class 1	12	60	1,813	42	97.7
Class 2	10	18	1,747	172	90.2
Class 3	3	16.5	32,533	63	99.8
Class 5	1	4	480	32	93.3
Class 6	2	6	5,313	277	94.8
Class 7	1	1	2,158	64	97.0
Class 8	2	5	1,762	0	100.0
Class 9	1	4	1,152	32	97.2
Class 10	2	1.3	921	0	100.0
Class 11	1	30	2,848	384	86.5
Class 12	4	63.2	297	7	97.6
Class 13	1	2	136	64	52.9

Classes 4 and 14 were not represented in 1927. Classes 5, 7, 9, 11, and 13 were represented by only one field each, and for that reason the figures representing these classes are not sufficiently representative to be used in forming conclusions. Aside from the classes mentioned above, the greatest larval survival was found in class 2. The fields in this class received no treatment in addition to the usual farm operations used in preparing land. The fields representing class 1 were also treated in the usual way, but in addition the plant remnants were removed from the surface after the fields had been completely prepared for planting. This added operation resulted in the destruction of approximately 7 per cent of the overwintering larvae. In general, the larval survival was very low in fields which were burned, although the survival in the single field representing class 11 was approximately 14 per cent. Since this class was represented by only one field, the information obtained was merely indicative. The average larval survival for all groups was approximately 2.5 per cent. The observations were completed before the emergence of corn-borer moths occurred, and it appeared that enough overwintering larvae had been destroyed to insure a substantial reduction in the 1927 infestation throughout the area in which the observations were made.

Observations made during the summer of 1927 in approximately 50 fields representing the same area as that represented by the counts from débris indicated that the destruction of approximately 97.5 per cent of the overwintering larvae resulted in a reduction in infestation amounting to approximately 18 per cent of the 1926 infestation. These observations were made in a comparatively small, severely infested area in the vicinity of Silver Creek, N. Y., and they should not be confused with similar observations made throughout a comparatively large area in Michigan, Ohio, Pennsylvania, and New York, under the supervision of L. H. Worthley and D. J. Caffrey.

IN 1928

In the spring of 1928 a clean-up campaign similar to the one conducted in the spring of 1927 was carried on by the United States Department of Agriculture, cooperating with the departments of agriculture of the various States in the infested area. Observations

were again made in approximately 50 fields located within a radius of 5 miles of Silver Creek, the same procedure being followed as in the previous year. The results of the observations in 1928 verified the information obtained from the investigations conducted in 1927, and indicated that approximately 90 per cent of the overwintering larvae were destroyed as a result of ordinary cultural practices. No burning was done during the campaign of 1928, but the débris was collected from many fields after they had been prepared for planting, and the results of this operation verified similar results obtained after the campaign of 1927.

Only four classes were represented by the 50 fields examined in the spring of 1928, consequently no detailed table is given for that year. The average apparent destruction of overwintering larvae in all fields in which the observations of 1928 were made was 98 per cent. Since the destruction of overwintering larvae in the clean-up campaign of 1928 was practically the same as in the campaign conducted in 1927, it seemed probable that the decrease in the infestation in 1928 would be about equal to the decrease in 1927. As a matter of fact, the decrease in 1928 amounted to 32 per cent of the 1927 infestation, as compared to a decrease in 1927 amounting to approximately 18 per cent of the 1926 infestation. The increased reduction was undoubtedly the result of natural conditions in 1928, which were less favorable to the borer than conditions in 1927.

IN 1929

No clean-up campaign was conducted in the spring of 1929, although farmers were requested to continue the operations which they had practiced during the two previous years. No equipment was used for burning, and no farmers were found who had collected débris after the fields were ready for planting. It was noted, however, that more care had been taken by the average farmer in preparing his land, and the quantity of débris left on the soil surface was noticeably less than usual. Observations made in the spring of 1929 in 35 fields indicated that approximately 95 per cent of the overwintering larvae were missing, slightly less than in 1928, when the destruction of approximately 98 per cent was indicated. Since fewer overwintering larvae were destroyed than in the previous year, it appeared that the infestation in 1929 might be slightly greater than in 1928, or that the decrease, if there was one, would be much smaller than the decrease in 1928. In reality the decrease amounted to 46 per cent of the 1928 infestation. In general, the results of the observations of débris in 1929 verified previous results, although two of the five classes included in the observations for 1929 were represented by only one field each. It was apparent that yearly increases and decreases in infestation did not depend entirely upon the number of larvae surviving from the previous year's infestation. The results of the examinations of débris in 1929 are recorded in Table 11.

TABLE 11.—*Records of examinations of débris made in commercial plantings of corn Silver Creek, N. Y., 1929*

Classification of fields according to treatment	Number of fields examined	Total area in fields	Average number of borers per acre		Reduction in average number of borers per acre
			Before treatment	After treatment	
		Acres			*Per cent*
Class 1	1	2	1,053	0	100.0
Class 2	18	57.5	1,654	89	94.6
Class 4	1	1.5	4,385	0	100.0
Class 5	2	2.5	5,975	198	96.7
Class 14	13	51.87	1,789	78	95.6

Observations had been made in 1928 to determine the percentage of corn-borer eggs which actually hatched and produced full-grown larvae. The observations were made in fields of sweet and field corn planted on various dates and in various locations. Under these average conditions it was found that 30.3 full-grown larvae were produced from every 100 eggs deposited. Similar observations in 1929 indicated that only 15 full-grown larvae were produced from every 100 eggs deposited. Moths were about equally plentiful during both years. The season of 1929 was noticeably dry, and the corn crop in the vicinity of Silver Creek was almost a failure. These two factors undoubtedly were the cause of the decided reduction in larvae in 1929. Had the production of full-grown larvae in 1929 been equal to that of 1928, it is evident that the infestations in 1928 and 1929 would have been about equal.

SUMMARY AND CONCLUSIONS

The first experiments in western New York in connection with the burying of corn-borer larvae as a means of corn-borer control were conducted in the fall of 1920 and the spring of 1921 during the course of an intensive clean-up campaign carried on by the United States Department of Agriculture. Many larvae were buried in pits, 24 inches or more in depth, and observations made at later dates in these pits indicated that 100 per cent of the larvae had been destroyed. Because of the labor involved, the burying of larvae to depths of 24 or more inches was an impractical operation, but the results obtained from these early experiments indicated that a practical method of destroying larvae by burying might be developed.

During the period from the fall of 1921 to the spring of 1924 various experiments were conducted which involved the burial of larvae by hand in various types of soil and in different seasons of the year. Some were buried in cages, while others were placed in the ground with no restrictions of any kind. In general, the conditions under which these burials by hand were conducted were decidedly unnatural, and it was evident that the results of such observations would not necessarily be applicable under natural field conditions. These experimental conditions, however, enabled the writers to observe the movements of the buried larvae much more closely than would have been possible under field conditions, and the knowledge obtained from such burials was of great value in tracing the movements of larvae when buried under natural conditions. Many of the buried larvae were

recovered on the surface of the soil, either in specially prepared traps or in sections of cornstalks. It was possible to sift the soil throughly and examine it carefully for the presence of dead larvae. The fact that a number of head capsules were recovered from the soil surrounding the buried material indicated that some of the missing larvae died and disintegrated in the soil.

The amount of migration observed varied only slightly in the several types of soil, and it was apparent that no particular type could be recommended as being particularly effective in reducing the migration of buried larvae to the soil surface. A greater mortality was indicated when larvae were buried in late fall than when they were buried earlier in the season while the soil temperature was comparatively high. Little or no spring activity of buried larvae was noted until April 1, or until the soil temperature reached approximately 40° F. The hand burials indicated that many larvae, when buried to a depth of 6 inches, were capable of reaching the soil surface, and that such larvae were in good condition and capable of producing fertile adults. It was found that such migrating larvae often hibernated in cornstalks or other plant material on the surface of the ground, when such material was available.

The plowing experiments were started in the fall of 1923 and were continued to the spring of 1927. Traps were used in all experiments, although some were placed at a distance of 12½ feet from the places of burial. Some of the experiments were conducted with no surface litter of any kind present, while in others 30 linear feet of uninfested cornstalks per square rod were supplied. The plowings were all approximately 6 inches in depth, and the soil was a clay loam representative of the soil of the surrounding country. Many larvae were recovered on the surface of the soil, either within sections of cornstalks or in the corrugated-paper traps. In general, the larvae that reached the surface in the plowing experiments received less protection from birds, insects, and the elements than those larvae that reached the surface in the hand-burial experiments.

The number of larvae found in the traps of spring plowings located 12½ feet from the places of burial on the soil surface of which there was no débris, was more than twice as great as the number of larvae reaching the traps 12½ feet from the places of burial where cornstalks were placed on the soil surface at the rate of 30 linear feet per square rod. In other words, a large number of the migrating larvae took advantage of the protection afforded by cornstalks when the latter were available. It is quite probable that a much larger number of migrating larvae would have found protection in débris if the traps had not checked their migration. More than three times as many larvae were found in the traps located adjacent to the burials when no débris was used than in similar traps when 30 linear feet of débris per square rod was placed on the surface of the ground. Approximately two-thirds of the migrating larvae hibernated in the sections of cornstalks placed on the soil surface. No definite statement can be made concerning the fate of migrating larvae when no protection was afforded in the form of traps or plant material, but the fact that there are many records of the destruction of corn-borer larvae by robins and other birds indicates very strongly that practically all of the migrating larvae which failed to obtain shelter of some kind were destroyed by birds or insects.

Observations conducted in commercial plantings of corn to determine the amount of larval mortality resulting from various methods of disposing of plant remnants showed very plainly the importance of cleanly plowing under all plant remnants. Even where the best of conditions prevailed, corn stubs and other plant remnants were brought to the surface by frost and by cultivation. When such plant débris was allowed to remain on the surface of the land, many migrating larvae took refuge in it, survived the winter and spring months, and produced normal adults.

Clean plowing, regardless of when it was done, was shown to be of great importance in reducing the overwintering population of corn-borer larvae. In most cases it was necessary and advisable to supplement the usual farm operations with the removal of plant débris from the soil surface as soon as the land had been made ready for planting. Fall plowing usually resulted in greater larval mortality than spring plowing, and from this particular standpoint fall plowing might be preferable. This apparent advantage, however, was offset by the fact that fall-plowed material was brought to the surface in large quantities by frost. This surface débris offered ideal protection to migrating larvae, and the labor required to collect and destroy it was an undesirable factor connected with fall plowing.

U. S. GOVERNMENT PRINTING OFFICE: 1931

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